Michigan High School Science

BIOLOGY

Prerequisite, Essential, and Core

Content Statements and Expectations

CE • **RIGOR** • RELEVANCE • RELATIONSHIPS • RIGOR • RE
IPS • RELATIONSHIPS • RIGOR • **RELEVANCE** • RELAT
CE • RIGOR • RELEVANCE • RELATIONSHIPS • RIGOR • RE
IPS • **RELATIONSHIPS** • RIGOR • RELEVANCE • RELAT

MICHIGAN Department of Education

Science Work Group

Planned Academic Review

Andy Anderson, Co-Chair
Michigan State University

Robert Poel, Co-Chair
Western Michigan University, (ret.)

Theron Blakeslee
Ingham ISD

Carol Clark
MI Dept. Labor & Economic Growth

Brian Coppola
University of Michigan

Mark Davids
Grosse Pointe South High School

Claudia Douglass
Central Michigan University

Kaz Fujita
Michigan State University

George Goff
Detroit King High School

Annis Hapkiewicz
Okemos High School, (ret.)

Marilyn Rands
Lawrence Technological University

Walter Rathkamp
Saginaw Valley State University

Kevin Richard
Michigan Department of Education

Judy Ruddock
Flint Public Schools, (ret.)

Sandra Rutherford
Eastern Michigan University

Michael Seymour
Hope College

Randy Showerman
MI Dept. Labor & Economic Growth

Betty Underwood
Michigan Department of Education

Planned Internal Review

Larry Calser
Genesee Math Science Center

Paul Drummond
Macomb ISD

Michael Gallagher
Oakland Schools

Shamarion Green
Flint Schools

Joseph Grigas
Lake Fenton High School

Cheryl Hach
Kalamazoo Math Science Center

Ardis Herrold
Grosse Pointe South High School

Michael Klein
Macomb ISD

Dave Peters
East Kentwood High School

Kevin Richard
Michigan Department of Education

Gary Waterson
Benzie Central High School

Project Coordinator

Susan Codere Kelly
Michigan Department of Education

Welcome to Michigan's High School Science Content Standards and Expectations

Why Develop Content Standards and Expectations for High School?

In 2004, the Michigan Department of Education embraced the challenge to initiate a "high school redesign" project. Since then, the national call to create more rigorous learning for high school students has become a major priority for state leaders across the country. The Cherry Commission Report highlighted several goals for Michigan including the development of high school content expectations that reflect both a rigorous and a relevant curricular focus. Dovetailing with this call to "curricular action" is Michigan's legislative change in high school assessment. The Michigan Merit Exam, based on rigorous high school learning standards, is to be full implemented by 2007.

The Michigan Department of Education's Office of School Improvement led the development of high school content expectations. A science academic review group of academicians chaired by nationally known scholars was commissioned to conduct a scholarly review and identify content standards and expectations. The Michigan Department of Education will conduct an extensive field review of the expectations by high school, university, and business and industry representatives.

The Michigan High School Science Content Expectations (Science HSCE) establish what every student is expected to know and be able to do by the end of high school and define the expectations for high school science credit in Earth and Space Science, Biology, Physics, and Chemistry.

An Overview

This is a first draft of Science Content Expectations for Michigan High Schools. It was developed by the Science Academic Review Work group. In developing these expectations, the group depended heavily on the *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2006).
In particular, the group adapted the structure of the NAEP framework (including Content Statements, Performance Expectations, and Boundaries). These expectations align closely with the NAEP framework, which is based on *Benchmarks for Science Literacy* (AAAS Project 2061, 1993) and the *National Science Education Standards* (National Research Council, 1996).

The academic review group carefully analyzed other documents, including the Michigan Curriculum Framework Science Benchmarks (2000 revision), the Standards for Success report *Understanding University Success*, ACT's *College Readiness Standards*, College Board's *AP Biology, AP Physics, AP Chemistry,* and *AP Environmental Science Course Descriptions*, ACT's *On Course for Success*, South Regional Education Board's *Getting Ready for College-Preparatory/Honors Science: What Middle Grades Students Need to Know and Be Able to Do,* and standards documents from other states.

Earth & Space Science	Biology	Physics	Chemistry
STANDARDS *(and number of Content Statements in each standard)*			
E1 Systems and Processes in the Environment (4) E2 The Solid Earth (4) E3 The Fluid Earth (4) E4 Earth in Space and Time (9) E5 Chemicals in the Environment (3)	B1 Organization and Development of Living Systems (6) B2 Interdependence of Living Systems and the Environment (4) B3 Genetics (6) B4 Evolution and Biodiversity (3)	P1 Forms of Energy and Energy Transformations (24) P2 Motion of Objects (3) P3 Forces and Motion (10)	C1 Forms of Energy (5) C2 Energy Transfer and Conservation (5) C2 Properties of Matter (10) C3 Changes in Matter (8)

Useful and Connected Knowledge for All Students

This draft defines expectations for Michigan High School graduates, organized by discipline: Earth and Space Science, Biology, Physics, and Chemistry. It defines ***useful*** and ***connected knowledge*** at three levels:

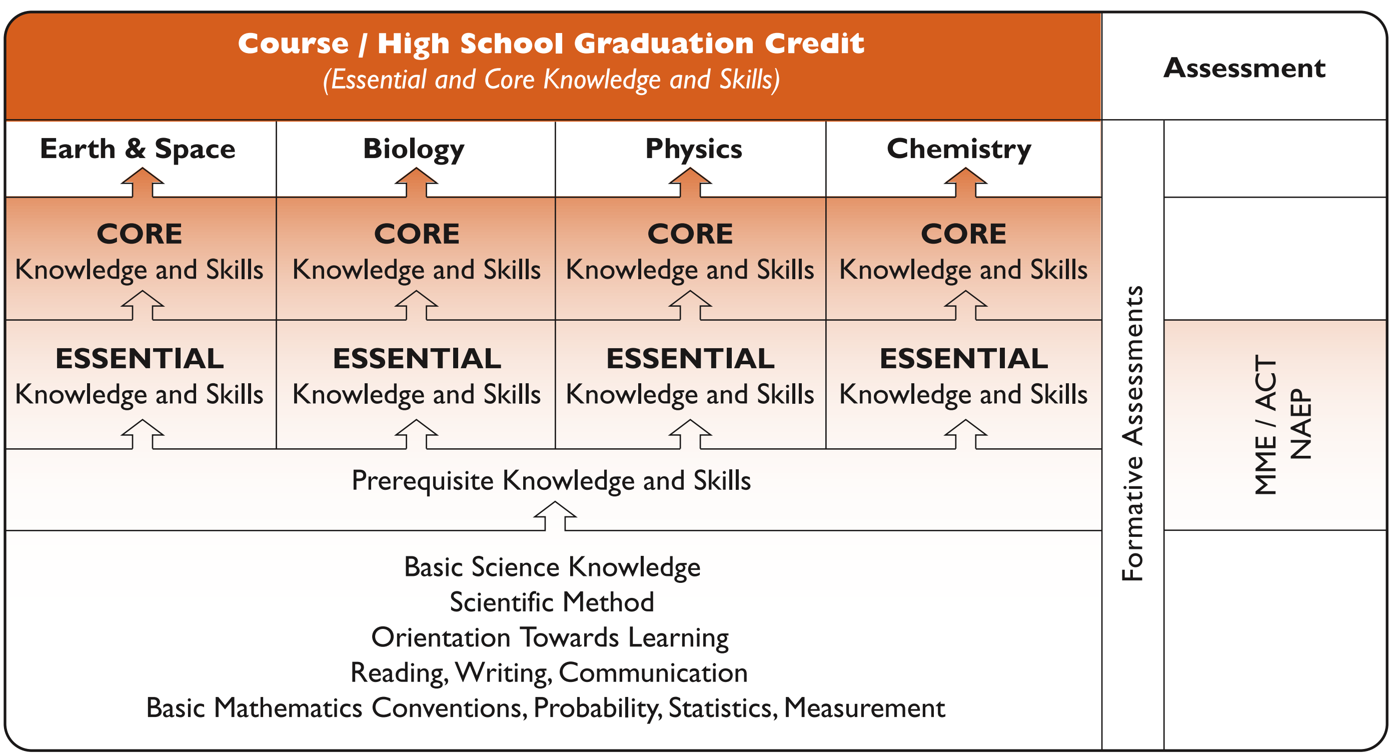
- **Prerequisite knowledge**
  Useful and connected knowledge that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed in the Essential category. Prerequisite content statements and expectations will be included in the middle school science expectations when they are written.

- **Essential knowledge**
  Useful and connected knowledge for all high school graduates, regardless of what courses they take in high school. In general, essential knowledge consists of content and skills that all students need to know and be able to do. Essential content and expectations will be assessable on large-scale assessments (MME/ACT, NAEP).

- **Core knowledge**
  Useful and connected knowledge for students who have completed a discipline-specific course. In general, core knowledge includes content and expectations that students need to be prepared for more advanced study in that discipline.

Useful and connected knowledge is contrasted with ***procedural display***—learning to manipulate words and symbols without fully understanding their meaning. When expectations are excessive, procedural display is the kind of learning that takes place. Teachers and students "cover the content" instead of striving for useful and connected knowledge.

Credit for high school Earth and Space Science, Biology, Physics, and Chemistry will be defined as meeting both essential and core subject area content expectations.



High School Science Overview

Preparing Students for Successful Post-Secondary Engagement

Students who have useful and connected knowledge should be able to apply knowledge in new situations; to solve problems by generating new ideas; to make connections among what they read and hear in class, the world around them, and the future; and through their work, to develop leadership qualities while still in high school. In particular, high school graduates with useful and connected knowledge are able to engage in four key practices of science literacy.

Successful Post-Secondary Engagement

Practices of Science Literacy

Communicate accurately and effectively...

Identifying Science Principles

- Describe, measure, or classify observations
- State or recognize correct science principles
- Demonstrate relationships among closely related science principles
- Demonstrate relationships among different representations of principles

Using Science Principles

- Explain observations of phenomena
- Predict observations of phenomena
- Suggest examples of observations that illustrate a science principle
- Propose, analyze, and evaluate alternative explanations or predictions

Scientific Inquiry

- Generate new questions that can be investigated empirically.
- Design and critique aspects of scientific investigations.
- Conduct scientific investigations using appropriate tools and techniques, recognizing limitations.
- Identify patterns in data and/or relate patterns in data to theoretical models.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions.
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable.
- Gather data and organize the results in graphs, tables, and/or charts.

Reflection and Technology

- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Identify and critique arguments based on scientific evidence.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Propose or critique solutions to problems given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Apply scientific models or patterns in data to technological design decisions.

State/National Landscape

- Expert perspective
- Education reform environment
- Research-based practices
- Work force requirements

State/Federal Expectations

- No Child Left Behind (NCLB)
- National Governors' Association (NGA)
- Legislation/Policy

Michigan High School Science Content Standards and Expectations

Earth and Space Science

Biology

Physics

Chemistry

Models for District Alignment / Mapping

- District curriculum documents
- Documents from other districts/states
- Backmapping to standards and expectations

Other MI Documents/Programs

- State Standards – teaching and learning, content (all areas), assessment
- Grade Level Content Expectations
- State Assessments
- Career/Technical Education Department of Labor and Economic Growth

K-8 Educational Experience

Content Knowledge

- English Language Arts
- Mathematics
- Science
- Social Studies
- Other

Learning Processes

- Strategies & Skills
- Reasoning
- Analytical Thinking
- Constructing New Meaning
- Communication

This chart includes talking points for the professional development model.

Practices of Science Literacy

- **Identifying**
  Indentifying performances generally have to do with stating models, theories, and patterns inside the triangle in Figure 1.
- **Using**
  Using performances generally have to do with the downward arrow in Figure 1—using scientific models and patterns to explain or describe specific observations.
- **Inquiry**
  Inquiry performances generally have to do with the upward arrow in Figure 1—finding and explaining patterns in data.[1]
- **Reflecting and Technology**
  Reflecting and *Technology* performances generally have to do with the figure as a whole (reflecting) or the downward arrow (technology as the application of models and theories to practical problems.

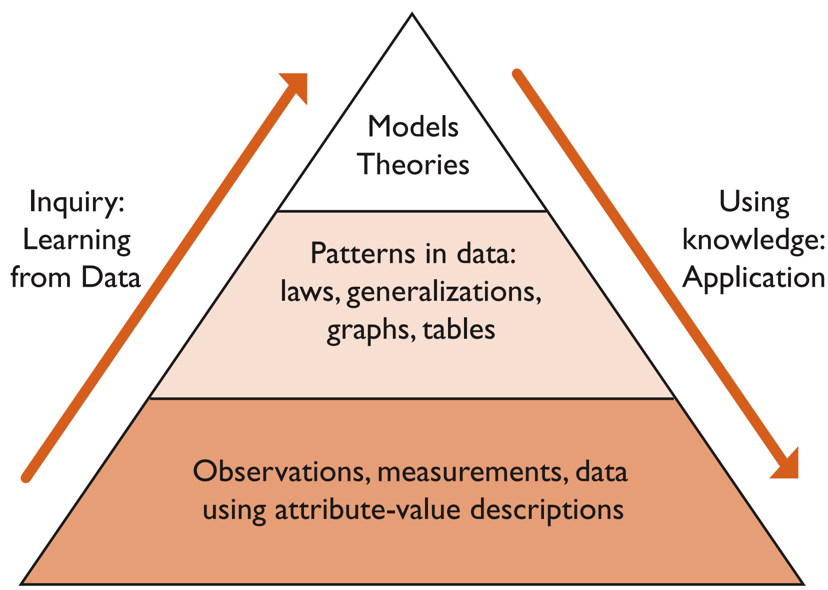


Figure 1: Knowledge and practices of model-based reasoning

Identifying Science Principles

This category focuses on students' ability to recall, define, relate, and represent basic science principles. The content statements themselves are often closely related to one another conceptually. Moreover, the science principles included in the content statements can be represented in a variety of forms, such as words, pictures, graphs, tables, formulas, and diagrams (AAAS, 1993; NRC, 1996). Identifying practices include describing, measuring, or classifying observations; stating or recognizing principles included in the content statements; connecting closely related content statements; and relating different representations of science knowledge.

Identifying Science Principles comprises the following general types of practices:

- Describe, measure, or classify observations (e.g., describe the position and motion of objects, measure temperature, classify relationships between organisms as being predator/prey, parasite/host, producer/consumer)
- State or recognize correct science principles (e.g., "mass is conserved when substances undergo changes of state;" "all organisms are composed of cells;" "the atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor")
- Demonstrate relationships among closely related science principles (e.g., statements of Newton's three laws of motion, energy transfer and the water cycle)
- Demonstrate relationships among different representations of principles (e.g., verbal, symbolic, diagrammatic) and data patterns (e.g., tables, equations, graphs)

Identifying Science Principles is integral to all of the other science practices.

Using Science Principles

Scientific knowledge is useful for making sense of the natural world. Both scientists and informed citizens can use patterns in observations and theoretical models to predict and explain observations that they make now or that they will make in the future.

Using Science Principles comprises the following general types of performance expectations:

- Explain observations of phenomena (using science principles from the content statements)
- Predict observations of phenomena (using science principles from the content statements, including quantitative predictions based on science principles that specify quantitative relationships among variables)
- Suggest examples of observations that illustrate a science principle (e.g., identify examples where the net force on an object is zero; provide examples of observations explained by the movement of tectonic plates; given partial DNA sequences of organisms, identify likely sequences of close relatives)
- Propose, analyze, and evaluate alternative explanations or predictions

The first two categories—***Identifying Science Principles*** and ***Using Science Principles***—both require students to correctly state or recognize the science principles contained in the content statements. A difference between the categories is that Using Science Principles focuses on what makes science knowledge valuable—that is, its usefulness in making accurate predictions about phenomena and in explaining observations of the natural world in coherent ways (i.e., "knowing why"). Distinguishing between these two categories draws attention to differences in depth and richness of individuals' knowledge of the content statements. Assuming a continuum from "just knowing the facts" to "using science principles," there is considerable overlap at the boundaries. The line between the Identifying and Using categories is not distinct.

Scientific Inquiry

Scientifically literate graduates make observations about the natural world, identify patterns in data, and propose explanations to account for the patterns. Scientific inquiry involves the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses to explain patterns in data. Scientific inquiry is a complex and time-intensive process that is iterative rather than linear. Habits of mind—curiosity, openness to new ideas, informed skepticism—are part of scientific inquiry. This includes the ability to read or listen critically to assertions in the media, deciding what evidence to pay attention to and what to dismiss, and distinguishing careful arguments from shoddy ones. Thus, Scientific Inquiry depends on the practices described above—Identifying Science Principles and Using Science Principles.

Scientific Inquiry comprises the following general types of performance expectations:

- Generate new questions that can be investigated in the laboratory or field.
- Design and critique aspects of scientific investigations (e.g., involvement of control groups, adequacy of sample)
- Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision)
- Identify patterns in data and/or relate patterns in data to theoretical models
- Describe a reason for a given conclusion using evidence from an investigation.
- Explain how scientific evidence supports or refutes claims or explanations of phenomena.
- Predict what would happen if the variables, methods, or timing of an investigation were changed.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions (e.g., check to see that the premises of the argument are explicit, notice when the conclusions do not follow logically from the evidence given)
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts.

Scientific inquiry is more complex than simply making, summarizing, and explaining observations, and it is more flexible than the rigid set of steps often referred to as the "scientific method." The *National Standards* makes it clear that inquiry goes beyond "science as a process" to include an understanding of the nature of science (p. 105). Further:

It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations (p. 171).

When students engage in Scientific Inquiry, they are drawing on their understanding about the nature of science, including the following ideas (see Benchmarks for Science Literacy):

- Arguments are flawed when fact and opinion are intermingled or the conclusions do not follow logically from the evidence given
- A single example can never support the inference that something is always true, but sometimes a single example can support the inference that something is not always true
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables
- The way in which a sample is drawn affects how well it represents the population of interest. The larger the sample, the smaller the error in inference to the population. But, large samples do not necessarily guarantee representation, especially in the absence of random sampling

Students can demonstrate their abilities to engage in Scientific Inquiry in two ways: students can *do* the practices specified above, and students can *critique examples* of scientific inquiry. In *doing*, practices can include analyzing data tables and deciding which conclusions are consistent with the data. Other practices involve hands-on performance and/or interactive computer tasks—for example, where students collect data and present their results or where students specify experimental conditions on computer simulations and observe the outcomes. As to *critiquing*, students can identify flaws in a poorly designed investigation or suggest changes in the design in order to produce more reliable data. Students should also be able to critique print or electronic media—for example, items may ask students to suggest alternative interpretations of data described in a newspaper article. For more on item formats, please see Chapter Four.

Reflection and Technological Design

Scientifically literate people recognize the strengths and limitations of scientific knowledge, which will provide the perspective they need to use the information to solve real-world problems. Students must learn to decide who and what sources of information they can trust. They need to learn to critique and justify their own ideas and the ideas of others. Since knowledge comes from many sources, students need to appreciate the historical origins of modern science and the multitude of connections between science and other disciplines. Students need to understand how science and technology support one another and the political, economic, and environmental consequences of scientific and technological progress. Finally, it is important that the ideas and contributions of men and women from all cultures be recognized as having played a significant role in scientific communities.

In both the *National Standards* and *Benchmarks*, the term "technological design" refers to the process that underlies the development of all technologies, from paperclips to space stations. Technological Design describes the systematic process of applying science knowledge and skills to solve problems in a real-world context. The reason for including technological design in the science curriculum is clearly stated in the *National Standards*: "Although these are science education standards, the relationship between science and technology is so close that any presentation of science without developing an understanding of technology would portray an inaccurate picture of science" (p. 190).

Reflection and Technological Design include the following general types of practices, all of which entail students using science knowledge to:

- Critique whether questions can be answered through scientific investigations.
- Identify and critique arguments based on scientific evidence.
- Compare the effectiveness of different graphics and tables to describe patterns, explanations, conclusions, and implications found in investigations.
- Explain why results from a single investigation or demonstration are not conclusive.
- Explain why a claim or a conclusion is flawed (e.g. limited data, lack of controls, weak logic).
- Propose or critique solutions to problems, given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Apply science principles or data to anticipate effects of technological design decisions.
- Explain the social, economic, and environmental advantages and risks of new technology.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Discuss topics in groups by making clear presentations, restating or summarizing what others have said, asking for clarification or elaboration, taking alternative perspectives, and defending a position.

Organization of the Expectations

The Science Expectations are organized into Disciplines, Standards, Content Statements, and specific Performance Expectations.

Disciplines

Earth and Space Science, Biology, Physics and Chemistry.

Organization of Each Standard

Each standard includes four parts, described below.

- A standard statement that describes what students who have mastered that standard will be able to do.
- Content statements that describe Prerequisite, Essential, and Core science content understanding for that standard.
- Performance expectations that describe Prerequisite, Essential, and Core performances for that standard.
- Boundary statements that clarify the standards to set limits to expected performances.

Standard Statement

The Standard Statement describes how students who meet that standard will engage in Identifying, Using, Inquiry, or Reflection for that topic.

Content Statements

Content statements describe the Prerequisite, Essential, and Core *knowledge* associated with the standard. This draft identifies five levels of expectations:

1. ***Prerequisite science content*** that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed with Essential content and printed in the left-hand column of the expectations documents.
2. ***Essential science content*** that all high school graduates should master. Essential content and expectations are organized by topic (e.g., E4.2 Earth in Space) and printed in the left-hand column of the expectations documents.
3. ***Core science content*** that high school graduates need for more advanced study in the discipline and for some kinds of work. Core content and expectations are organized by topic (e.g., E4.3x Stars; note that "x" designates a core topic) and printed in the right-hand column of the expectations document.
4. ***Basic mathematics skills.*** These will be included in an Appendix at the end of the document.
5. ***Basic English language arts skills.*** These will be included in an Appendix at the end of the document.

Performance Expectations

Performance expectations are derived from the intersection of content statements and practices—if the content statements from the Earth and Space Sciences, Biology, Physics, and Chemistry are the columns of a table and the practices (Identifying Science Principles, Using Science Principles, Using Scientific Inquiry, Reflection and Technological Design) are the rows, the cells of the table are inhabited by performance expectations.

Performance expectations are written with particular verbs indicating the desired performance expected of the student. The action verbs associated with each practice are not firmly fixed. The use of any action verb must be contextualized. For example, when the "conduct scientific investigations" is crossed with a states-of-matter content statement, this can generate a performance expectation that employs a different action verb, "heats as a way to evaporate liquids."

Boundaries

Boundaries elaborate the Performance Expectations. The boundaries are intended as "notes to curriculum and assessment developers," not as comprehensive descriptions of the full range of science content to be included in the high school science curriculum. In the boundary statements, the terms "such as," "including," "e.g.," and "etc." are used to denote suggestions. The boundaries do not stand alone and should be considered in conjunction with the relevant content statements and narrative introductions for each of the disciplines—Earth and Space Science, Biology, Physics, and Chemistry. Some content statements are very detailed and require less specification of boundaries. Although the boundaries relevant to a given subtopic may focus more heavily on some content statements than others, this is not intended to denote a sense of content priority.

BIOLOGY (B)

The structure of living systems directly influences how they carry out their life functions. Reasoning about living systems often involves relating different levels of organization, from the molecule to the biosphere, and understanding how living systems are structured at each level. Cells are made of complex organic molecules and are the basic unit of life. Organisms can be either single-celled or multicellular. Multicelluar organisms have specialized cells to carry out specific functions.

Energy plays a crucial role in all aspects of every living thing, from the molecular to the global level. The food-making process of photosynthesis generates the energy source, in the form of organic compounds, for all living things. This energy is transferred in ecosystems via food chains and webs. The energy found in organic chemical bonds is changed to usable cellular energy through the process of cellular respiration.

Life processes in a cell are based on molecular interactions which keep the internal environment relatively constant. Cells are composed of highly organized structures called organelles. Cells are the smallest unit of life that can assimilate energy, reproduce, react to the environment, etc. A collection of cells with a common function form a tissue and several kinds of tissues form an organ. Together many organs form an organ system such as the digestive system. A multicellular organism is the composite of cells, tissues, and organs

It is essential that genetic information be passed from parents to offspring. This is accomplished as genetic material is passed from parent to offspring in the development of gametes and then fertilization units the genetic information from both parents creating a unique individual Organisms within a species are generally similar because they posses very similar genetic material. However, genetic mixing and occasional mutation result in differences among individuals. Over time, changes in genetic information can affect the size, diversity, and genetic composition of populations, a process called biological evolution.

Earth's present day life forms have evolved from common ancestors by a process of natural selection. Evolution is the unifying principle that provides the framework for organizing most of biological knowledge into a coherent picture. Evidence for evolution is found in the fossil record and is indicated by anatomical and chemical similarities evident within the diversity of existing organisms.

Outline of Biology Expectations

STRUCTURE AND FUNCTIONS OF LIVING SYSTEMS

Standard B1: Organization and Development of Living Systems

B1.1 Cellular Specialization
B1.2 Organic Molecules
B1.2x Proteins
B1.3 Maintaining Environmental Stability
B1.3x Homeostasis
B1.4 Cell Specialization
B1.5 Living Organism Composition
B1.5x ATP
B1.6x Internal/ External Cell Regulation

Standard B2: Interdependence of Living Systems and the Environment

B2.1 Ecosystems
B2.2 Element Recombination
B2.3 Changes in Ecosystems
B2.3x Human Impact
B2.4 Populations
B2.4x Environmental Factors

CHANGES IN LIVING SYSTEMS

Standard B3: Genetics

B3.1 Genetics and Inherited Traits
B3.2 DNA
B3.3x RNA and Protein Synthesis
B3.4 Sexual Reproduction
B3.5x Genetic Variation
B3.6x Recombinant DNA

Standard B4: Evolution and Biodiversity

B4.1 Theory of Evolution
B4.2 Molecular Evidence
B4.3 Natural Selection

Standard B1: Organization and Development of Living Systems

Standard Statement

Students describe the general structure and function of cells. They can explain that all living systems are composed of cells and that organisms may be unicellular or multicellular. They understand that cells are composed of biological macromolecules and that the complex processes of the cell allow it to maintain a stable internal environment necessary to maintain life. They make predictions based on these understandings.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **L[*]1.p1:** All organisms are composed of cells, from just one cell to many cells. Over two-thirds of the weight of a cell is accounted for by water, which gives cells many of their properties. In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of organisms for food, air, and waste removal. The way in which cells function is similar in all living organisms.*(Prerequisite)* ***Identifying and Using Performance Expectations*** ▪ Distinguish between living and nonliving systems. ▪ Explain the importance of both water and the element carbon to cells. ▪ Describe growth and development in terms of increase in cell number, cell size, and/or cell products ▪ Explain how the systems in a multicellular organism work together to support the organism. ▪ Compare and contrast how different organisms accomplish similar functions (e.g., obtain oxygen for respiration, excrete waste).	
Content Statement **L1.p2:** *Prerequisite:* Following fertilization, cell division produces a small cluster of cells that then differentiate by appearance and function to form the basic tissues of an embryo. ***Identifying and Using Performance Expectations*** ▪ Describe how through cell division, cells can become specialized for specific function. ▪ Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of	***Identifying and Using Performance Expectation*** ▪ Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.

the embryo.	
Content Statement **L1.p3:** *Prerequisite:* Cells carry out the many functions needed to sustain life. They grow and divide, thereby producing more cells. Food is used to provide energy for the work that cells do and is a source of the molecular building blocks from which needed materials are assembled. ***Identifying and Using Performance Expectations*** ▪ Describe how organisms sustain life by obtaining, transporting, transforming, releasing, and eliminating matter and energy. ▪ Describe the effect of limiting food to developing cells. ▪ Predict what would happen if essential elements were withheld from developing cells.	
Content Statement **L1.p4:** *Prerequisite:* Plants are producers—they use the energy from light to make sugar molecules from the atoms of carbon dioxide and water. Plants use these sugars, along with minerals from the soil, to form fats, proteins and carbohydrates. This food can be used immediately, incorporated into the cells of a plant as the plant grows, or stored for later use. ***Identifying and Using Performance Expectations*** ▪ Explain the significance of carbon in organic molecules. ▪ Explain the origins of plant mass. ▪ Predict what would happen to plants growing in low-carbon-dioxide atmospheres. ▪ Explain how the roots of specific plants grow. Content Clarification: Plants capture energy by absorbing light and using it to form chemical bonds between the atoms of sugar molecules. These sugar molecules can be used to make amino acids and other carbon-containing (organic) molecules and assembled into larger molecules with biological activity (including proteins, DNA, carbohydrates, and fats).	
Content Statement **L1.p5:** *Prerequisite:* All animals, including humans, are consumers, which obtain food by eating other organisms or their products. Consumers break down the structures of the organisms they eat to obtain the materials they need to grow and function. Decomposers, including bacteria and fungi, use dead organisms or their products for food. ***Identifying and Using Performance Expectations*** ▪ Classify different organisms based on how they obtain energy for growth and development. ▪ Explain how an organism obtains energy from the food it consumes.	
Content Statement **L1.p6:** *Prerequisite:* Living systems are made of complex molecules that consist mostly of a few elements, especially carbon, hydrogen, oxygen, nitrogen, and phosphorous.	

Identifying and Using Performance Expectations ▪ Recognize the six most common elements in organic molecules (C, H, N, O, P, S). ▪ Identify the most common complex molecules that make up living organisms. *** Please Note**: The code **L**1.p6 indicates the listed prerequisite is from anticipated middle school **Life** Science content statements. This is different than the **Biology** course content expectations, coded with a "**B**".	
Content Statement **B1.1 Cell Specialization** In multicellular organisms, cells are specialized to carry out specific functions such as transport, reproduction, or energy transformation. ***Identifying and Using Performance Expectations*** **B1.1A** Explain how cells transform energy (ultimately obtained from the sun) from one form to another through the processes of photosynthesis and respiration. Identify the reactants and products in the general reaction of photosynthesis. **B1.1B** Compare and contrast the transformation of matter and energy during photosynthesis and respiration. **B1.1C** Compare and contrast ways in which selected cells are specialized to carry out particular life functions. **B1.1D** Explain growth and development as a consequence of an increase in cell number, cell size, and/or cell products. **Technical Vocabulary** Energy transformation, reactant, product, growth, development	
Content Statement **B1.2 Organic Molecules** There are four major categories of organic molecules that make up living systems: carbohydrates, fats, proteins, and nucleic acids. ***Identifying and Using Performance Expectations*** **B1.2A** Explain how carbon can join to other carbon atoms in chains and rings to form large and complex molecules. **B1.2B** Recognize the six most common elements in organic molecules (C, H, N, O, P, S). **B1.2C** Describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids). **B1.2D** Explain the primary functions of the major complex organic molecules that compose living organisms. **Technical Vocabulary** Enzyme, organic, sugar, phosphate, carbohydrate, lipid, protein, nucleotide base ***Content Clarification:*** **Carbohydrates** are made of C, H, and O arranged in chains of glucose molecules. Carbohydrates provide and store energy.	***Content Statement*** **B1.2x Proteins** Proteins are composed mostly of amino acids and are made of C, H, O, and N, and function as enzymes, structural components, and hormones. ***Identifying and Using Performance Expectations*** **B1.2e** Explain the role of enzymes in biochemical reactions. **B1.2f** Describe how proteins control life functions (e.g., the proteins myosin and actin interact to cause muscular contraction; the protein hemoglobin carries oxygen in some organisms). **B1.2g** Propose how moving an organism to a new environment may influence it ability to survive and predict the possible impact of this type of transfer. ***Content Clarification*** **Enzymes** are proteins that catalyze chemical reactions in living systems. Enzymes function only in specific reactions and within narrow physical conditions. They speed reactions and allow them to proceed at lower temperatures.

Lipids serve as long term energy sources and as insulation and are made of C, H, and O arranged in long chains insoluble in water. **Proteins** may be structural or may function in transport, movement, defense, or cell regulation. Proteins are composed mostly of amino acids and are made of C, H, O, and N. **Nucleic acids** (DNA and RNA) are made of C, H, O, N, and P; they function as messengers and carry genetic information.	**Nucleic acids** are composed of a sugar, a phosphate, and a nucleotide base (made of C, H, O, N, and P); they function as messengers and carry genetic information.
Content Statement **B1.3 Maintaining Environmental Stability** The internal environment of living things must remain relatively constant. Many systems work together to maintain stability. Stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents. ***Identifying and Using Performance Expectations*** **B1.3A** Describe how cells function in a narrow range of physical conditions, such as temperature and pH (acidity), to perform life functions that help to maintain homeostasis. **B1.3B** Describe how the maintenance of a relatively stable internal environment is required for the continuation of life. **B1.3C** Explain how stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents. **Technical Vocabulary** Homeostasis, pH ***Content Clarification:*** Most organisms can tolerate small changes in pH. Most cells function best within a narrow range of temperature and pH. At very low temperatures, reaction rates are too slow. High temperatures or extremes of pH can change the structure or proteins and later their function.	***Content Statement*** **B1.3x Homeostasis** The internal environment of living things must remain relatively constant. Many systems work together to maintain homeostasis. When homeostasis is lost, death occurs. ***Identifying and Using Performance Expectations*** **B1.3d** Describe how organisms maintain a stable internal environment using the circulatory, endocrine, excretory, and immune response systems. **B1.3e** Describe how the human body maintains relatively constant internal conditions (temperature, acidity, and blood sugar). **B1.3f** Explain how human organ systems help maintain human health. **B1.3g** Compare the structure and function of a human body system or subsystem to a nonliving system (e.g., human joints to hinges, enzyme and substrate to interlocking puzzle pieces).
Content Statement **B1.4 Cell Specialization** In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of cells for food, air, and waste removal. The way in which cells function is similar in all living organisms. ***Identifying and Using Performance Expectations*** **B1.4A** Describe ways in which living things can be classified based on each organism's internal and external structure, their development, and relatedness of DNA sequence. **B1.4B** Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes. **B1.4C** Describe how various organisms have developed different specializations to accomplish a particular function and yet the end result is the same (e.g., excreting nitrogenous wastes in animals, obtaining oxygen for respiration). **B1.4D** Explain how different organisms accomplish the same result using different structural specializations (gills vs. lungs	***Content Statement*** **B1.4x Cell Specialization** In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of cells for food, air, and waste removal. The way in which cells function is similar in all living organisms. ***Identifying and Using Performance Expectations*** **B1.4e** Explain how cellular respiration is important for the production of ATP (build on aerobic vs. anaerobic). **B1.4f** Recognize and describe that both living and nonliving things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP. **B1.4g** Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.

vs. membranes). **Technical Vocabulary** ATP, cellular respiration, aerobic, anaerobic, prokaryote, eukaryote, endosymbiotic theory, mitochondrion, chloroplast, organelle?, potential energy ***Boundary Limit Expectations:*** All living things have similar requirements for life. Students should focus on the common functions of cells and organ systems that allow them to transform energy and carry out cellular functions. This standard does not address ancestral commonalities leading to evidence for evolution.	***Content Clarification:*** Modern cells have within them structures that may have existed as free-living cells. The mitochondria appear to be the descendants of bacteria as do the plastids in plant cells. The idea that organelles descended from free-standing bacteria is called the endosymbiotic theory. ***Content Clarification:*** Cellular respiration allows living things to transfer the energy they acquire into a form usable by the cell, ATP. ATP supplies the energy for most living things. It stores potential energy in its high energy phosphate-to-phosphate bonds.
Content Statement **B1.5 Living Organism Composition** All living or once living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates and lipids contain many carbon-hydrogen bonds that also store energy. ***Identifying and Using Performance Expectations*** **B1.5A** Recognize and explain that macromolecules such as lipids contain high energy bonds. **B1.5B** Explain how major systems and processes work together in animals and plants, including relationships between organelles, cells, tissues, organs, organ systems, organisms; relate to molecular functions. **B1.5C** Describe how energy is transferred and transformed from the Sun to energy-rich molecules during photosynthesis. **B1.5D** Describe how individual cells break down energy-rich molecules to provide energy for cell functions. **Technical Vocabulary** Diffusion, osmosis, active transport, protein synthesis, plasma/cell membrane ***Content Clarification:*** Prokaryotic cells do not have membrane-bound organelles and are therefore considered more primitive than eukaryotic cells. Eukaryotic have several organelles that carry out specialized functions. All multicellular organisms are composed of eukaryotic cells.	***Content Statement*** **B1.5x ATP** All living or once living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates and lipids contain many carbon-hydrogen bonds that also store energy. However, that energy must be transferred to ATP to be usable by the cell. ***Identifying and Using Performance Expectations*** **B1.5e** Explain the interrelated nature of photosynthesis and cellular respiration. **B1.5f** Relate plant structures and functions to the process of photosynthesis and respiration. **B1.5 g** Compare and contrast plant and animal cells. **B1.5 h** Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport). **B1.5i** Relate cell parts/organelles to their function. ***Content Clarification:*** Plant cells capture the energy of the sun in photosynthesis and store it for later use as carbohydrates. Through cellular respiration carbohydrates are broken down and energy is transferred to ATP where it is accessible for use by the cell. ***Content Clarification:*** Organelles are highly organized structures that are found in eukaryotic cells. Most are bound by membranes and contain specialized structures that allow them to carry out specific functions such as protein synthesis, packaging of cellular chemicals, and transfer of energy. *Content Clarification:* The plasma membrane surrounds the cell providing a protective, yet fluid barrier to the environment. Membrane structure allows for some molecules to move in and out of the cells.

	Content Statement **B1.6x Internal/External Cell Regulation** Cellular processes are regulated both internally and externally by environments in which cells exist, including local environments that lead to cell differentiation during the development of multicellular organisms. During the development of complex multicellular organisms, cell differentiation is regulated through the expression of different genes. **B1.6a** Describe how dehydration and hydrolysis relate to organic molecules. **B1.6b** Identify the general functions of the major systems of the human body (digestion, respiration, reproduction, circulation, excretion, protection from disease, and movement, control, and coordination) and describe ways that these systems interact with each other. **B1.6c** Explain that the regulatory and behavioral responses of an organism to external stimuli occur in order to maintain both short- and long-term equilibrium. **B1.6d** Explain that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Note that cell behavior can also be affected by molecules from other parts of the organism, such as hormones. **B1.6e** Recognize and explain that communication and/or interaction are required between cells to coordinate their diverse activities. **B1.6f** Explain how higher levels of organization result from specific complex interactions of smaller units and that their maintenance requires a constant input of energy as well as new material. **B1.6g** Analyze the body's response to medical interventions such as: organ transplants, medicines, and inoculations. **Technical Vocabulary** Cell differentiation, gene expression, cell cycle?, dehydration reaction, hydrolysis reaction, regulartory response, behavioral response, external stimulus, equilbirium
Inquiry, Reflection, and Technology Performances	
B1.R1 Discuss how microscopes, advanced microscopy, and other technologies have contributed to our knowledge of cell function and structure. **B1.R2** Design and conduct experiments that demonstrate how decomposers use dead material as growth medium. **B1.R3** Design an experiment and record results of transplanting cells in developing embryos. **B1.R4** Design and discuss results of an experiment that limits essential elements from the medium of developing cells. **B1.R5** Investigate and distinguish between prokaryotic cells and eukaryotic cells, in terms of their general structures and degrees of complexity.	**B1.r7** Identify a biological topic that was dependent upon technological advancements. Research that topic and engage in a discussion of the advantages that technology provided and the disadvantages of the use of technology. For example, chemotherapy has allowed patients with cancer to be cured; however it interferes with normal cell division and often causes much discomfort to the patient. Tissue culturing has been a tremendous advancement in the treatment of burn victims. Yet some people are opposed to it because it is not natural. **B1.r8** Describe technologies used in the prevention,

B1.R6 Illustrate how the modern cell theory exemplifies how scientific knowledge usually grows slowly, through contributions from many different investigators from diverse cultures.	diagnosis, and treatment of diseases and explain their functions in terns of human body processes. **B1.r9** Investigate how technology is used to improve the health of individuals. **B1.r10** Design, conduct, collect data, and analyze an experiment in which the homeostatic control of organisms is challenged (e.g., culture of bacteria or mold exposed to temperature extremes). **B1.r11** Design and experiment that demonstrates how enzyme function is influenced by environmental differences (temperature or pH). **B1.r12** Design an experiment to demonstrate that the organic compounds produced by plants are the primary source of energy and nutrients for most living things, using isotopes. **B1.r13** Design and conduct and experiments that would trace the movement of food materials from a food source to a structural component of another organism.

Standard B2 – Interdependence of Living Systems and the Environment

Standard Statement

Students describe the processes of photosynthesis and cellular respiration and how energy is transferred through food webs. They recognize and analyze the consequences of the dependence of organisms on environmental resources and the interdependence of organisms in ecosystems.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **L2.p1** *Prerequisite:* Organisms acquire their energy directly or indirectly from sunlight. Plants capture the sun's energy and turn it into food through the process of photosynthesis. Through the process of cellular respiration, animals are able to release the energy stored in the molecules produced by plants and use it for cellular processes. ***Identifying and Using Performance Expectations*** Draw an aquatic and terrestrial food web using arrows to show the flow of energy. Describe how organisms acquire energy directly or indirectly from sunlight. Draw a food web including humans.	***Identifying and Using Performance Expectations*** ▪ Illustrate and describe the energy conversions that occur during photosynthesis and respiration. ▪ Recognize the equations for photosynthesis and respiration and identify the reactants and products for both. ▪ Write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean. ▪ Summarize the process of photosynthesis including o cells trap energy from sunlight with chlorophyll, and use the energy, carbon dioxide, and water to produce energy-rich organic molecules and oxygen; o photosynthesis involves an energy conversion in which light energy is converted to chemical energy in specialized cells (e.g., plants and some protists).
Content Statement	

L2.p2 *Prerequisite:* Organisms of one species form a population. Populations of different organisms interact and form communities. Living communities and the nonliving factors that interact with them form ecosystems. ***Identifying and Using Performance Expectations*** ▪ Provide examples of a population, community, and ecosystem.	
Content Statement **L2.p3:** *Prerequisite* Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other. ***Identifying and Using Performance Expectations*** ▪ Describe common relationships among organisms and provide examples of producer/consumer, predator/prey, or parasite/host relationship. ▪ Describe common ecological relationships between and among species and their environments (competition, territory, carrying capacity, natural balance, population, dependence, survival, and other biotic and abiotic factors). ▪ Describe the role of decomposers in the transfer of energy in an ecosystem. ▪ Explain how two organisms can be mutually beneficial and how that can lead to interdependency. ▪	
Content Statement **L2.p4:** (*Prerequisite)* The number of organisms and populations an ecosystem can support depends on the biotic resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. ***Identifying and Using Performance Expectations*** Identify the factors in an ecosystem that influence fluctuations in population size. Distinguish between the living (biotic) and nonliving (abiotic) components of an ecosystem. Explain how biotic and abiotic factors cycle in an ecosystem (water, carbon, oxygen, and nitrogen). Predict how changes in one population might affect other populations based upon their relationships in a food web.	
Content Statement **L2.p5** *(Prerequisite)* All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organisms or other organisms, whereas others are beneficial. ***Identifying and Using Performance Expectations*** Recognize that and describe how human beings are part of Earth's ecosystems. Note that human activities can deliberately or inadvertently alter the equilibrium	

in ecosystems.	
Content Statement **B2.1 Ecosystems** The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in an ecosystem, some energy is stored in newly made structures, but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. ***Identifying and Using Performance Expectations*** **B2.1A** Identify where energy is stored in an ecosystem. **B2.1B** Describe energy transfer through an ecosystem accounting for energy lost to the environment as heat. **B2.1C** Draw the flow of energy through an ecosystem. Predict changes in the food web when one or more organisms are removed. **Technical Vocabulary** Heat, aquatic, terrestrial, chlorophyll, population, community, ecosystem	***Identifying and Using Performance Expectations*** **B2.1d** Describe how carbon and other nutrients cycle through an ecosystem.
Content Statement **B2.2 Element Recombination** As matter cycles and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change. ***Identifying and Using Performance Expectations*** **B2.2A** Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life. **B2.2B** Use a food web to identify and distinguish producers, consumers, and decomposers, and explain the transfer of energy through trophic levels. **B2.2C** Diagram and describe the stages of the life cycle for a human disease-causing organism. **Technical Vocabulary** Conservation of matter, conservation of energy, nutrient cycling, trophic level, food chain, food web, energy transfer, producer, consumer, predator, prey, parasite, decomposer, host, scavenge, competition, adaptation, dependence	
Content Statement **B2.3 Changes in Ecosystems** Although the interrelationships and interdependence of organisms may generate biological communities in ecosystems that are stable for hundreds or thousands of years, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution. The impact of the human species has major consequences for other species.	***Content Statement*** **B2.3x Human Impact** Humans can have tremendous impact on the environment. Sometimes their impact is beneficial and sometimes it is detrimental.

Identifying and Using Performance Expectations

B2.3A Describe ecosystem stability. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

B2.3B Recognize and describe that a great diversity of species increases the chance that at least some living organisms will survive in the face of large (cataclysmic?) changes in the environment.

B2.3c Examine the effects of human activities such as reducing the amount of forest cover, increasing the chemicals released into the atmosphere, and intensive farming have changed the Earth's land, oceans, and atmosphere and also its capacity to support life forms.

Technical Vocabulary
Migration, succession, greenhouse effect, global warming, species diversity, deforestation, pollution

Identifying and Using Performance Expectations

B2.3d Describe the greenhouse effect and list possible causes.
B2.3e List the possible consequences of global warming.

Content Statement

B2.4 Populations

Populations of living things increase and decrease in size as they interact with other populations and with the environment. The rate of change is dependent upon relative birth and death rates.

Identifying and Using Performance Expectations

B2.4A Graph changes in population growth given a data table.
B2.4B Explain the influences that affect population growth including those characteristic of the organism and environmental influences.
B2.4C Predict the consequences of an invading organism on the survival of other organisms.

Technical Vocabulary
Birth rate, death rate, carrying capacity, exponential growth

Content Statement

B2.4x Environmental Factors

Population growth occurs in different patterns as influenced by environmental factors. A very rapid increase in organisms occurs when environmental resources are not limited; as resources decrease, the rate of increase decreases until the population (usually) stabilizes at the carrying capacity for that geographical area.

Identifying and Using Performance Expectations

B2.4d Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.

B2.4e Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.

B2.4f Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.

Inquiry, Reflection, and Technology Performances

B2.R1 Analyze and graph changes in an ecosystem resulting from natural causes, changes in climate, human activity, technology, or introduction of non-native species. Use data to make predictions.
B2.R2 Predict the impact of human population growth on the environment and the survival of other organisms in given situations.
B2.R3 Locally, or in a larger geographical area such as the Great Lakes watershed, identify and describe an ecosystem, including
- effects of biotic and abiotic components
- examples of interdependence
- evidence of human influences
- energy flow and nutrient cycling
- diversity analysis
- ecological succession.

B2.r4 Apply the concepts of population dynamics to the human population and identify factors affecting changes in population size.

Identifying and Using Performance Expectations

B2.3A Describe ecosystem stability. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

B2.3B Recognize and describe that a great diversity of species increases the chance that at least some living organisms will survive in the face of large (cataclysmic?) changes in the environment.

B2.3c Examine the effects of human activities such as reducing the amount of forest cover, increasing the chemicals released into the atmosphere, and intensive farming have changed the Earth's land, oceans, and atmosphere and also its capacity to support life forms.

Technical Vocabulary
Migration, succession, greenhouse effect, global warming, species diversity, deforestation, pollution

Identifying and Using Performance Expectations

B2.3d Describe the greenhouse effect and list possible causes.
B2.3e List the possible consequences of global warming.

Content Statement

B2.4 Populations

Populations of living things increase and decrease in size as they interact with other populations and with the environment. The rate of change is dependent upon relative birth and death rates.

Identifying and Using Performance Expectations

B2.4A Graph changes in population growth given a data table.
B2.4B Explain the influences that affect population growth including those characteristic of the organism and environmental influences.
B2.4C Predict the consequences of an invading organism on the survival of other organisms.

Technical Vocabulary
Birth rate, death rate, carrying capacity, exponential growth

Content Statement

B2.4x Environmental Factors

Population growth occurs in different patterns as influenced by environmental factors. A very rapid increase in organisms occurs when environmental resources are not limited; as resources decrease, the rate of increase decreases until the population (usually) stabilizes at the carrying capacity for that geographical area.

Identifying and Using Performance Expectations

B2.4d Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.

B2.4e Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.

B2.4f Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.

Inquiry, Reflection, and Technology Performances

B2.R1 Analyze and graph changes in an ecosystem resulting from natural causes, changes in climate, human activity, technology, or introduction of non-native species. Use data to make predictions.
B2.R2 Predict the impact of human population growth on the environment and the survival of other organisms in given situations.
B2.R3 Locally, or in a larger geographical area such as the Great Lakes watershed, identify and describe an ecosystem, including

- effects of biotic and abiotic components
- examples of interdependence
- evidence of human influences
- energy flow and nutrient cycling
- diversity analysis
- ecological succession.

B2.r4 Apply the concepts of population dynamics to the human population and identify factors affecting changes in population size.

Standard B3: Genetics

Standard Statement

Students recognize that the specific genetic instructions for any organism are contained within genes composed of DNA molecules located in chromosomes. They explain the mechanism for the direct production of specific proteins based on inherited DNA. Students diagram how occasional modifications in genes and the random distribution of genes from each parent provide genetic variation and become the raw material for evolution. Content Statements, Performances, and Boundaries

<table>
<tr><th>Essential</th><th>Core</th></tr>
<tr><th colspan="2">Content Statements, Identifying and Using Performances</th></tr>
<tr><td>Content Statement
L3.p1 Prerequisite: Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually.
Identifying and Using Performance Expectations
▪ Compare and contrast the differences between sexual and asexual reproduction.
▪ Discuss the advantages and disadvantages of sexual vs. asexual reproduction.
▪ Explain how example organisms reproduce (e.g., bacteria, yeast, flowering plants, insects, birds, mammals)</td><td></td></tr>
<tr><td>Content Statement
L3.p2 Prerequisite: The characteristics of organisms are influenced by heredity and environment. For some characteristics, inheritance is more important; and for other characteristics, interactions with the environment are more important.
Identifying and Using Performance Expectations
▪ Explain that the traits of an individual are influenced by both the environment and the genetics of the individual. Acquired traits are not inherited. Only genetic traits are inherited.</td><td></td></tr>
<tr><td>Content Statement
B3.1 Genetics and Inherited Traits
Hereditary information is contained in genes, located in the chromosomes of each cell. Cells contain many thousands of different genes. One or many genes can determine an inherited trait of an individual, and a single gene can influence more than one trait. Before a cell divides, this genetic information must be copied and apportioned evenly into the daughter cells.</td><td>Identifying and Using Performance Expectations</td></tr>
</table>

Identifying and Using Performance Expectations **B3.1A** Draw and label a heterozygous chromosome pair highlighting a particular gene location. **B3.1B** Explain that the information passed from parents to offspring is transmitted by means of genes which are coded in DNA molecules. These genes contain the information for the production of proteins. **B3.1C** Differentiate between dominant, recessive, codominant, polygenic, and sex-linked traits. **B3.1D** Explain the genetic basis for Mendel's laws of segregation and independent assortment. **B3.1E** Describe a specific example of a gene controlling a trait, (i.e., Sickle cell anemia, other). **B3.1F** Determine the genotype and phenotype of monohybrid crosses using a Punnett Square. **Technical Vocabulary** Species, sexual reproduction, heredity, inheritance, trait (acquired/ inherited), gene, chromosome, heterozygous, homozygous, dominant, recessive, codominant, polygenic, sex-linked, segregation, independent assortment, genotype, phenotype, DNA sequence, Punnett square	**B3.1g** Explain that the similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a unique species, different from all others. Likewise, understand that every other species has its own characteristic DNA sequence. **B3.1h** Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules using virtually the same mechanism in all life forms.
Content Statement **B3.2 DNA** The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment. ***Identifying and Using Performance Expectations*** **B3.2A** Show that when mutations occur in sex cells, they can be passed on to offspring (inherited mutations), but if they occur in other cells, they can be passed on to descendant cells only (non-inherited mutations). **B3.2B** Recognize that every species has its own characteristic DNA sequence. **B3.2C** Describe the structure and function of DNA. **B3.2D** Predict the consequences that changes in the DNA composition of particular genes may have on an organism. **B3.2E** Propose possible effects (on the genes) of exposing an organism to radiation and toxic chemicals. **Technical Vocabulary** Mutation, DNA replication, transcription, translation, genetic engineering, recombinant DNA	***Identifying and Using Performance Expectations*** **B3.2f** Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms. **B3.2g** Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology. **B3.2h** Recognize that genetic engineering techniques provide great potential **B3.2i** Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes.

<table>
<tr>
<td></td>
<td>Content Statement
B3.3x RNA & Protein Synthesis
Protein synthesis begins with the information in a sequence of DNA bases being copied onto messenger RNA. This molecule moves from the nucleus to the ribosome in the cytoplasm where it is “read.” Transfer RNA brings amino acids to the ribosome where they are connected in the correct sequence to form a specific protein.

Identifying and Using Performance Expectations
B3.3a Describe the general pathway by which ribosomes synthesize proteins by using tRNAs to translate genetic information encoded in mRNAs.

Technical Vocabulary
Messenger RNA, nucleus, ribosome, transfer RNA, protein synthesis</td>
</tr>
<tr>
<td>Content Statement
B3.4 Sexual Reproduction
Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents.

Identifying and Using Performance Expectations
B3.4A Diagram the processes of cell division (mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations.
B3.4B Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring.
B3.4C Illustrate that the sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of two parents.
B3.4D Differentiate between mitosis and meiosis in terms of both process and significance.
B3.4E Explain how zygotes are produced in the fertilization process.
B3.4F Explain how it might be possible to identify genetic defects from just a few cells of an embryo.

Technical Vocabulary
Cell division, mitosis, meiosis, gamete, genetic recombination, fertilization, zygote, embryo</td>
<td>Identifying and Using Performance Expectations
B3.4g Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.
B3.4h Predict how mutations will be transferred to progeny.
B3.4i Explain that cellular differentiation results from gene expression and/or environmental influence.</td>
</tr>
</table>

	Content Statement **B3.5x Genetic Variation** Genetic variation is essential to biodiversity and the stability of a population. Genetic variation is ensured by the formation of gametes and their combination to form a zygote. Opportunities for genetic variation also occur during cell division when chromosomes exchange genetic material causing permanent changes in the DNA sequences of the chromosomes. Random mutations in DNA structure caused by the environment are another source of genetic variation. ***Identifying and Using Performance Expectations*** **B3.5a** Describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it, and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment. **B3.5b** Explain that gene mutation in a cell can result in uncontrolled cell division, called cancer. Also know that exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer. **B3.5c** Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and in its offspring. **Technical Vocabulary** Biodiversity, insertion, deletion, substitution, cancer
	Content Statement **B3.6x Recombinant DNA** Recombinant DNA technology allows scientists in the laboratory to combine the genes from different sources, sometimes different species, into a single DNA molecule. This manipulation of genes using bacterial plasmids has been used for many practical purposes including the mass production of chemicals and drugs. ***Identifying and Using Performance Expectations*** **B3.6a** Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. **B3.6b** Evaluate the advantages and disadvantages of human manipulation of DNA. **Technical Vocabulary** Recombinant DNA, bacterial plasmid
Inquiry, Reflection, and Technology Performances	
B3.R1 Conduct a family investigation of a particular gene trait; determine phenotype and predict genotypes of family members for three generations (i.e., tongue rolling, widow's peak, etc.) **B3.R2** Relate changes resulting from genetic engineering to real life. (B3.2)	**B3.r3** Design and conduct a simple dihybrid cross of two heterozygotes; use the results of the investigation to make reasonable inferences of how traits are inherited. **B3.r4** Predict the impact of genetic engineering on future products.

Standard B4: Evolution and Biodiversity

Standard Statement

Students recognize that evolution is the result of genetic changes that occur in constantly changing environments. They can explain that modern evolution includes both the concepts of common descent and natural selection. They illustrate how the consequences of natural selection and differential reproduction have led to the great biodiversity on Earth.

Content Statements, Performances, and Boundaries

Essential	Core
Content Statements, Identifying and Using Performances	
Content Statement **L4.p1:** Individual organisms with certain traits in particular environments are more likely than others to survive and have offspring. When an environment changes, the advantage or disadvantage of characteristics can change. Extinction of a species occurs when the environment changes and the characteristics of a species are insufficient to allow survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the Earth no longer exist. *(Prerequisite)* ▪ Define a species, and give examples. ▪ Define a population, and identify local populations. ▪ Explain how extinction removes genes from the gene pool. ▪ Explain the importance of the fossil record.	
Content Statement **L4.p2:** Similarities among organisms are found in anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance. *(Prerequisite)* ***Identifying and Using Performance Expectations*** ▪ Explain, with examples, that ecology studies the varieties and interactions of living things across space while evolution studies the varieties and interactions of living things across time.	
Content Statement **B4.1 Theory of Evolution** The Theory of Evolution provides a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. ***Identifying and Using Performance Expectations*** **B4.1A** Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending upon environmental conditions). **B4.1B** Describe how natural selection provides a mechanism for	

evolution. **B4.1C** Summarize the relationships between present-day organisms and those that inhabited the Earth in the past (e.g., use fossil record, embryonic stages, homologous structures, chemical basis). **B4.1D** Explain how a new species or variety may originate through the evolutionary process of natural selection. **B4.1E** Explain how natural selection leads to organisms that are well suited for the environment (differential survival and reproduction of chance inherited variants, depending upon environmental conditions). **B4.1F** Explain using examples how the fossil record, comparative anatomy, and other evidence support the theory of evolution. **B4.1G** Illustrate how genetic variation is preserved or eliminated from a population through Darwinian natural selection (evolution) resulting in biodiversity. **Technical Vocabulary** Natural selection, differential survival, evolution, homologous structures, comparative anatomy	
Content Statement **B4.2 Molecular Evidence** Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descents branched. ***Identifying and Using Performance Expectations*** **B4.2A** Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular similarities. **B4.2B** Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA and protein sequences. **B4.2C** Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of sub-populations. **Technical Vocabulary** Morphologic similarities, genetic drift, sub-population, cladogram, phylogenetic tree ***Add link from MSTA web site - Greg Forbes.***	***Identifying and Using Performance Expectations*** **B4.2d** Interpret a cladogram or phylogenetic tree showing evolutionary relationships among organisms.
Content Statement **B4.3 Natural Selection** Evolution is the consequence of natural selection, the interactions of (1) the potential for a population to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection from environmental pressure of those organisms better able to survive and leave offspring. ***Identifying and Using Performance Expectations***	***Identifying and Using Performance Expectations***

B4.3A Explain how natural selection acts on individuals, but it is populations that evolve. Relate genetic mutations and genetic variety produced by sexual reproduction to diversity within a given population. **B4.3B** Describe the structures of viruses and bacteria. **B4.3C** Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells. **B4.3D** Describe the role of geographic isolation in speciation. **B4.3E** Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms. **B4.3F** Explain how evolution through natural selection can result in changes in biodiversity through the increase or decrease of genetic diversity from a population. **Technical Vocabulary** Virus, bacteria, bacterial DNA, speciation Note: Find a spot for classification of plant, animal, bacteria, viruses, other without dwelling on details of complete classification system.	**B4.3g** Explain how changes at the gene level are the foundation for changes in populations and eventually the formation of new species. **B4.3h** Demonstrate and explain how biotechnology can improve a population and species.
Inquiry, Reflection, and Technology Performances	
B4.R1 Relate the extinction of species to a mismatch of adaptation and the environment.	**B4.r2** Explain that DNA technologies allow scientists to identify, study, and modify genes. Forensic identification is one example of DNA technology. **B4.r3** Explain the common beliefs about heredity before Darwin's *Origin of Species*, and the significance and success of this explanation of natural selection and heredity. **B4.r4** Explain how the rediscovery of Gregor Mendel's genetics experiments supported the theory of biological evolution suggested by Charles Darwin.
Boundaries Essential Technical Vocabulary ▪ homozygous, heterozygous, monohybrid, dihybrid, recessive, dominant, codominant, polygenic, sex-linked traits, Punnett Square, DNA, RNA Essential Foundational Knowledge ▪ basic computational skills, graphing, ratios, basic scientific design, hypothesis, theory. show first bullet as essential across discipline ▪ reproductive process, how DNA and genes are transferred from one generation to the next (mitosis, meiosis)	

MICHIGAN Department of Education
Office of School Improvement

Michigan Department of Education
Office of School Improvement
Dr. Yvonne Caamal Canul, Director
(517) 241-3147 www.michigan.gov/mde